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Agricultural Memorandum No. 740

BEEF HOUSING STUDIES - WORKING REPORT II

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1. Report I emphasised the role of siting in the ventilation performance of farm buildings.

   Each succeeding farm visit merely serves to reinforce the view that if the intensive housing of beef animals is to be satisfactory, the site and the house have to be as open as possible. Shelter, whether provided by the lie of the land, by hedges and trees, by adjacent buildings or feed stacks, by internal partitions, is commonly unneccessary and often positively disadvantageous.

   Two corollaries follow from this

   (i) there is little point in discussing the ventilation characteristics of particular designs of commercially available buildings in their own right, and independently of how and where they are positioned on the farm. Where the building will stand is as important as whether the building will stand.

   (ii) ventilation design should not be for adequate performance under average wind pressures, but for performance in the limiting situation of no wind pressure, ie ventilation by stack pressure,

2. The purpose of this note is to suggest a standard procedure for the making and interpretation of the observations possible with the present equipment.

2.1 Before anything other than hand-held equipment is taken to a farm, a preliminary visit is seen as desirable to establish potential hazards and difficulties.

   Points to be taken include
   - the siting of the building in relation to other obstacles to the free wind
   - internal accessibility
   - dangers from stock eg bull beef
   - availability and location of power supplies
   - the proposed siting of internal and external instruments.

2.2 The "throw" of the nitrous oxide "jet" from the cylinder is of the order 2-3 metres. Ideally, the sampling point should be at least this distance from the release point, though this may not always be possible.

   A short puff of tracer gas (cylinder release 1-3 minutes) may be adequate to give rise to peak instrument levels, but experience would suggest that the eddying flow that is then subsequently monitored is not readily interpreted. A 9-10 minute release, well upwind of the sampling point, and not directed at the sampling point gives results (chart records) that accord better with the theory that assumes perfect mixing and an exponential rate of decay.

   Samplings at the infra-red gas analyses should be at the maximum rate (2 litres/minute) and should continue until the observed concentration falls from a peak

of 1000 ppm (or 200 ppm on the lower scale range) to zero. Minimum duration of sampling time should be 3 minutes and preferably 5–10 minutes.

2.3 The tracer gas studies have to be supplemented by

(a) more conventional air speed measurements, both inside, outside and at ventilation openings

(b) temperature observations inside and outside

Both (a) and (b) can afford some check on the order of magnitude of the air change rate suggested by the tracer measurements.

3. INTERPRETATION OF RESULTS

3.1 LOCAL AIR RENEWAL RATE AT THE SAMPLING POINT

One estimate is given by the total time for the measured gas concentration to fall from a peak value C_1 at time t_1 to , a unit value (C_2) value at time t_2; this time includes recirculation delays to the decay rate. The rate, N changes/hour given by the expression

$$N = \frac{2.303 \, (\log_{10} C_1 - \log_{10} C_2) \times 60}{(t_2 - t_1) \text{ minutes}}$$

assumes perfect mixing, an exponential change of concentration, and gives an average rate over the sampling period.

3.2 RESIDENCE TIME AND VENTILATION RATE

The integral $\int_{t_1}^{t_2} C \, dt$ is given by the area under the concentration x time curve, and can be obtained directly from the recorder.

The integral $\int_{t_1}^{t_2} C.t\,dt$ may be approximated by the summation $\sum_{t_1}^{t_2} (Cdt)\, t$

- where dt in the time interval corresponding to 10 mm recorder chart intervals.
- Cdt is the area under the concentration x time curve over this time interval,
- t is the time from the initial observation at time t_1.

The residence time $$\bar{t} = \frac{\int_{t_1}^{t_2} C \, t \, dt}{\int_{t_1}^{t_2} C \, dt}$$

Following the work of Dankwerts (1958), the rate of exchange of fresh, inlet air, at any point in a system, may be defined as the reciprocal of the mean 'age' of the air at that point.

The ventilation rate R, which is the rate of removal of fresh, inlet air, has been defined as $R = 1/\bar{t}$

With t_1, t_2, covering the whole sampling period, we establish an average value for R.

3.3. THE RATIO R/N

With average values of R and N determined over the full sampling period (from tracer concentration peak to zero) ie, from the same data, over the same time interval, there are no great theoretical difficulties of interpretation.

Even when the physical situation is regarded as unsatisfactory, as when the distance between release and sampling point is of the order 2-3 metres, or when the observed change in concentration is attributed primarily to translation rather than to small scale eddy mixing of Figure 2, the ratio R/N appears to give consistent results.

eg FROSTENDEN HALL (JUNE 1975)

$R_{average}$	62	100	34	47	changes/hour
$N_{average}$	116	201	70	116	changes/hour
R/N	53%	50%	49%	63%	

The interpretation placed on these figures is that under the conditions prevailing, about one half of the local air renewal rate could be allocated to the arrival of fresh, inlet air, the remainder to recirculated air.

The suggestion is that the ratio may be used as a basis for comparison within and between houses at given points in time, but obviously either R or N have to be determined absolutely in some satisfactory manner.

3.4 ABSOLUTE VALUES OF N

With recorder chart speeds up to 120 mm/minute and with the time interval $t_1 - t_2$ possibly no more than 2-3 minutes in open, naturally ventilated systems, it is apparent that the procedures necessary to establish the ratio R/N will show detailed fluctuations in tracer concentration at the sampling point. Typical results are shown in Figures 1, 2 for sampling and release points at 2-3 metres separation and in Figure 3 for much greater separation of sampling and release points.

It is apparent that for open, naturally ventilated animal houses, that the common assumptions of perfect mixing of the inlet air and of the tracer gas, and of a uniform concentration through-out the compartment being studied, are not often going to be met, without gross modification and distortion of the system (such as would be made by the introduction of fans to impose some supplementary mixing).

If the expression for N is evaluated for time intervals much less than 1 minute, for example over 10 to 20 mm chart intervals, then it is found that over periods when the rate of change is a maximum, local air renewal rates of the order N =500 changes/hour may be implied. Such a figure is scarcely realistic over longer periods and one physical explanation which suggests itself is that the puff of tracer gas remains relatively discrete over this short time interval, with sharp boundaries. The observed change in concentration at the sampling point is then attributed to translation, rather than to dilution of the puff of tracer.

One avenue of enquiry that suggests itself is whether some assessment both of translation effects and of the eddying flow due to general internal air movements and entrainment can be made in some simple way from the data. This information could then be used to "normalise" the values of N inferred, and to obtain more realistic values that would accord with other field experience and have some prospect of general acceptance.

Unfortunately, the conclusion drawn from a spread of situations, having different internal and external air speeds is that short period, peak values of N, alone, or in combination with other factors such as the average value of N, or total sampling time, do not afford the basis for discrimination. Basically, what is inferred is something of eddy dimensions in time (or in space and time) and similar internal eddying motions are apparently to be found, independently of the overall air change or local air renewal rates.

To establish acceptable values of N, such as are to be inferred from the central portion of Figure 3, it appears necessary to have

(i) Considerable separation between release and sampling points (preferably at least 5 metres)

(ii) A long release of tracer (at least 3 minutes, preferably 5–10 minutes)

(iii) A long sampling period (at least 5–10 minutes from peak to zero values)

(iv) a recording chart speed which enables recirculation eddies to be identified and rejected. (as at the beginning and end of Figure 3).

In general, the lowest value of N inferred from sensible portions of the total sampling period seems the value to adopt as being indicative of the local air renewal rate over significantly longer periods; peak values of N, of the order 10 times this limiting value, can apparently be found over short periods in each and every situation.

4. Whilst these studies have some inferest in their own right to the environmental physicist, it has to be remembered that the study was sponsored by ADAS. Any association between what we measure and between animal and building performance is only likely to be achieved if other disciplines are prepared to try to understand and become involved in what we do, and if they contribute data from their own area of equal validity.

Meteorological Office
Cambridge
July 1975

5. RESULTS FROSTENDEN HALL JUNE 1975

PERIOD	CONCENTRATION x dt	CONCENTRATION x dt x t
1 (dt=1/12) minute	1450 mm^2 chart area	1450 x 1/12 mm^2 min
2	820	820 x 2/12
3	800	800 x 3/12
4	750	750 x 4/12 etc
5	600	
6	900	-
7	1050	
8	820	$\bar{t} = \frac{\int ct.dt}{\int c\ dt} = \frac{16070}{16690}$ minutes
9	750	
10	750	
11	780	
12	720	$\bar{t}$ = .016 hours
13	700	
14	600	$1/\bar{t}$ = R = 62/hour
15	450	
16	400	
17	380	
18	380	$N = \frac{138.18 \left[\log_{10} 200 - 0\right]}{33/12 \text{ minutes}}$ = 116/hour
19	350	
20	320	
21	320	
22	300	
23	230	
24	230	
25	220	R/N = 53%
26	220	
27	280	
28	280	
29	220	
30	200	
31	150	
32	110	
33	50	

5.2 From Figure 2

PERIOD	CONCENTRATION x dt	CONCENTRATION x dt x t
1	1400 mm^2 chart area	1400 x 1/12 mm^2 min.
2 (dt = 1/12 minute)	650	650 x 2/12
3	200	200 x 3/12
4	800	800 x 4/12
5	1550	1550 x 5/12 etc
6	1400	
7	1550	
8	1450	
9	800	$\bar{t} = \frac{\int ct.dt}{\int c\ dt} = \frac{6295}{10640}$ minutes
10	400	
11	350	
12	250	
13	200	$\bar{t}$ = .01 hours
14	200	
15	200	$1/\bar{t}$ = R = 100/hour
16	150	
17	50	
18	20	$N = \frac{138.18[\log_{10} 200-0]}{19/12 \text{ minutes}} = 201/hr$
19	20	

R/N = 50 %

FIGURE 1 FROSTENDEN HALL JUNE 1975

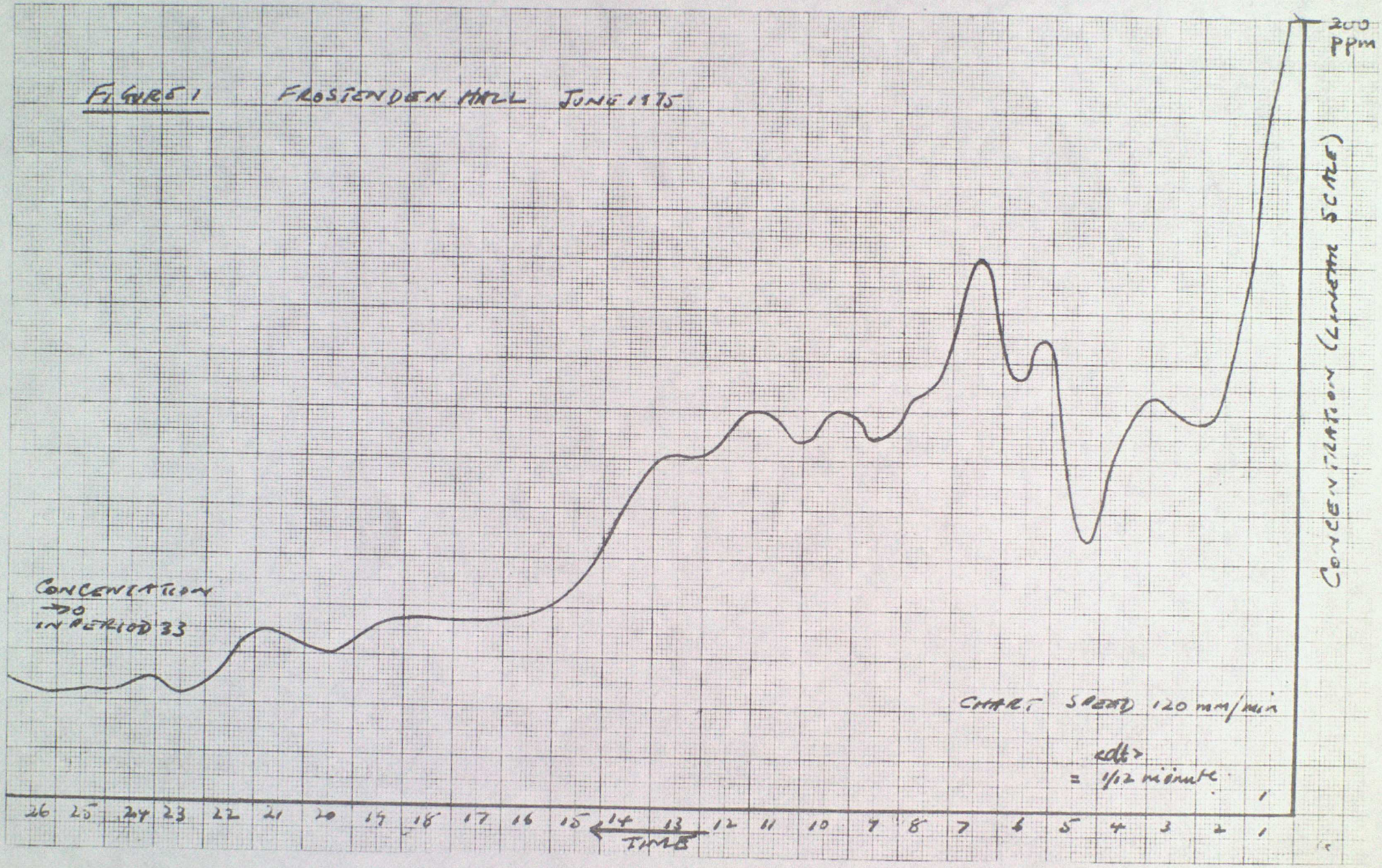
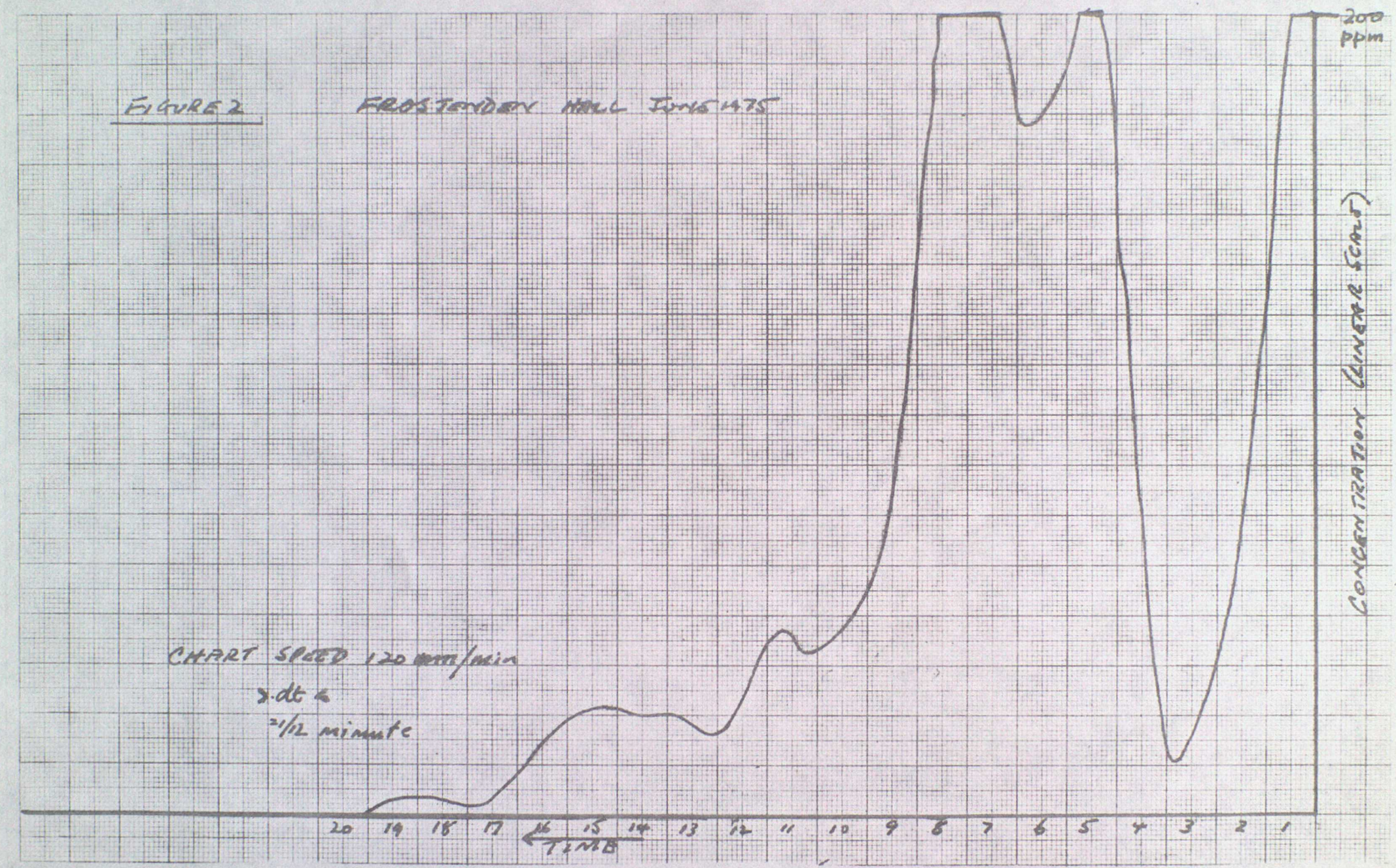

200 ppm
CONCENTRATION (LINEAR SCALE)
CONCENTRATION → 0 IN PERIOD 33
CHART SPEED 120 mm/min
<dt> = 1/2 minute
26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
TIME

FIGURE 2 FROSTBURG MILL JUNE 1975



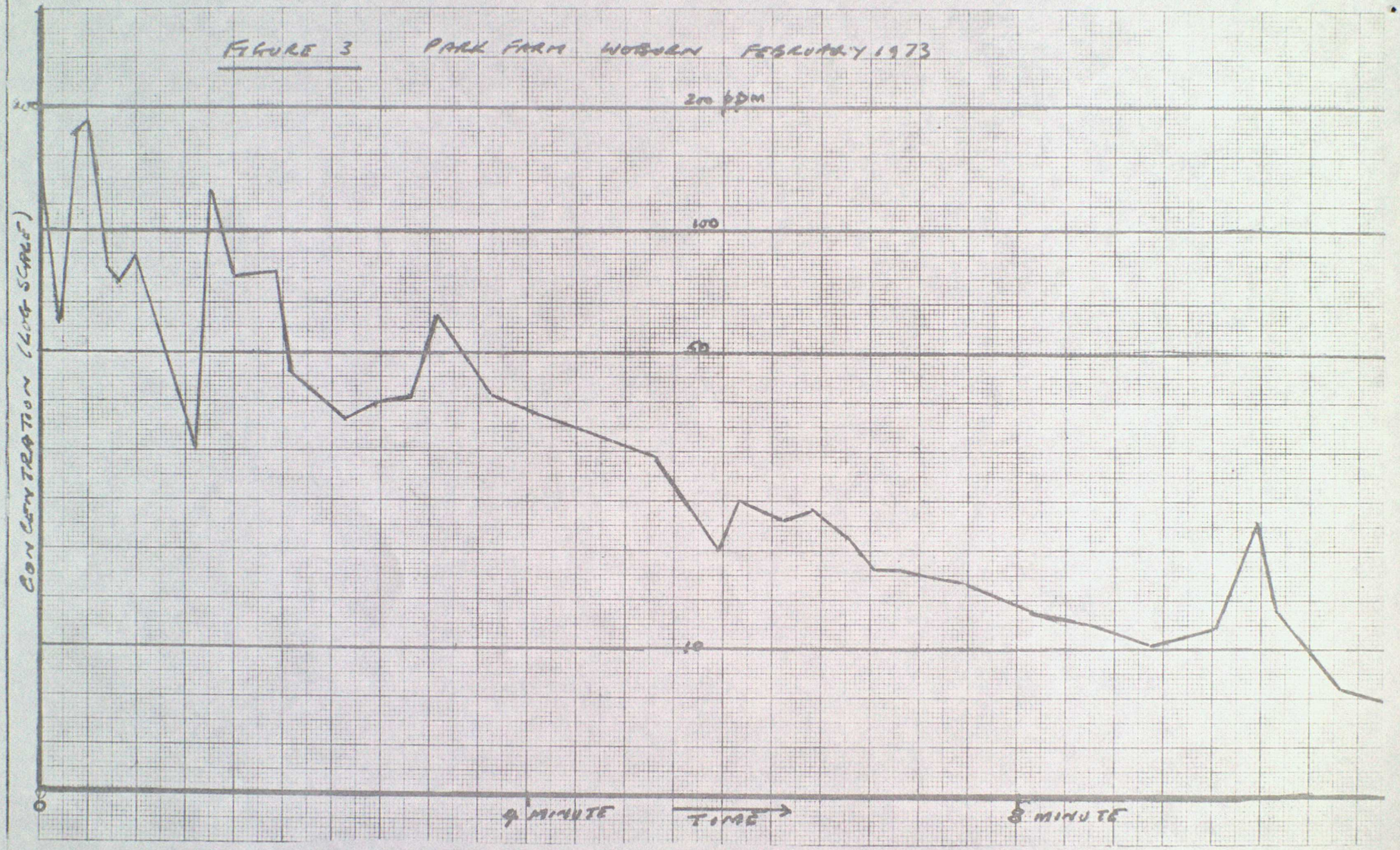


FIGURE 3 PARK FARM WOBURN FEBRUARY 1973
200 PPM
100
50
10
0
CONCENTRATION (LOG SCALE)
4 MINUTE
TIME
8 MINUTE